Ultrasonic Calibration Test Phantom

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We built a phantom, the Ultrasonic Calibration Test Phantom, consisting of vertical wires maintained under tension. The phantom is a valuable tool as an ultrasonic test, calibration, and reconstruction object for the LLNL annular array scanner.

Project Goals

Our goal was to build a reconfigurable ultrasonic phantom for the annular array scanner. Its intended use was to collect well-characterized data under controlled conditions for use as "canonical data sets" in testing and evaluating new inversion algorithms.

Relevance to LLNL Mission

The nondestructive evaluation (NDE) of objects and media of interest to LLNL, DOE, and DoD is an essential part of LLNL's mission. Many NDE situations have put demands beyond the scope of the current suite of imaging algorithms. As new algorithms and codes come on line, they must be evaluated on well-characterized phantoms. The Ultrasonic Calibration Test Phantom provides such a data set.

FY2004 Accomplishments and Results

We achieved our goal of building the Ultrasonic Calibration Test Phantom. The phantom consists of top and bottom plates into which are drilled holes through which wires are run. The holes form a geometrical pattern that governs the horizontal distribution of the wires. The plates are affixed to top and bottom mounting brackets that are pulled apart, putting the wires under tension. Given that the phantom object formed by the wire distribution does not vary much in the vertical (z) direction, we assume the measured data are from a 2.5-D object.

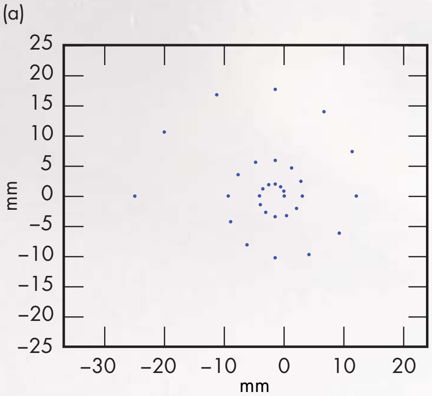
These plates are removable, permitting different configurations to be used. We currently have only one configuration: a logarithmic spiral with equation,

$$r(\theta_n) = \alpha(\cos(\theta_n), \sin(\theta_n))e^{b\theta_n},$$

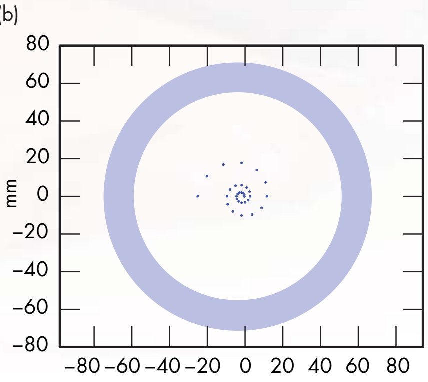
where

$\alpha \equiv \lambda_0$	is the initial radius and,
$\lambda_0 \equiv \upsilon_0 / f_0$	is the insonifying wavelength,
$\upsilon_0 \equiv 1500 \mathrm{m/s}$	is the assumed background water velocity,
$f_0 \equiv 1\mathrm{MHz}$	is the approximate insonifying frequency,
$b \equiv 10\pi/180$	is the spiral growth rate,
$\theta_n \equiv \{n\Delta\theta\}_{n=0}^{N-1}$	are the angular locations of the wires,
$\Delta\theta \equiv 30\pi/180$	is the angular increment,
$N \equiv 31$	is the number of wires.

(a)



(b)



(c)

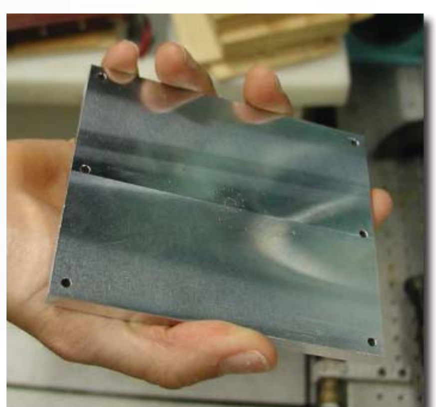
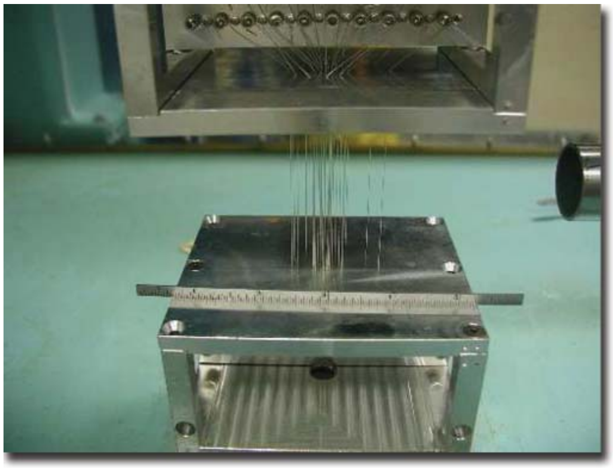


Figure 1. Basic spiral phantom design (a) without hollow cylinder, (b) with cylinder. (c) Photograph of wiring plate with holes.

(a)



(b)

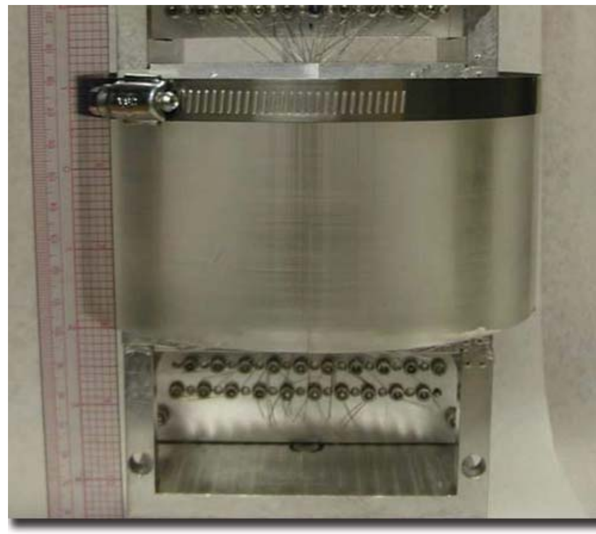


Figure 2. (a) Phantom after the wires were pulled taut. (b) Phantom with optional acrylic hollow cylinder.

Our current configuration is shown in Fig. 1. We have allowed for an optional acrylic hollow cylinder around the phantom as shown in Fig. 1b. Figure 1c shows one of the plates.

The phantom is secured into the scanner: the top block is affixed to a rod fastened to the central bore of the scanner drive; the bottom block is fastened to the bottom of the tank. Once installed, the blocks are pulled apart to render the wires taut. Figure 2a shows the phantom with 31 steel taut wires; Fig. 2b shows the optional acrylic cylinder in place.

We have run scans with the following combinations of materials:

- 31 steel wires
- 30 steel and one nylon wire
- 25 steel and six nylon wires
- 25 steel, and six nylon with a hollow cylinder
- two steel, two nylon resolution pair
- two steel, two nylon resolution pair with a hollow cylinder
- a hollow cylinder only (no wires)
- water only background run.

Related References

1. Lehman, S. K., and A. J. Devaney, "Transmission Mode Time-Reversal Super-Resolution Imaging," *Journal of the Acoustical Society of America*, **113**, (5), pp. 2742-2753, May 2003.

2. Devaney, A. J., and M. Dennison, "Inverse Scattering in Inhomogeneous Background Media," *Inverse Problems*, **19**, pp. 855-870, 2003.

3. Lehman, S. K., and S. J. Norton, "Radical Reflection Diffraction Tomography," *Journal of the Acoustical Society of America*, **116**, (4), October 2004.

FY2005 Proposed Work

We are very pleased with the quality of the measured data, which will be used as "canonical data sets" for testing new inversion and detection algorithms. The flexibility of the phantom allows us to create new models to simulate real NDE problems of interest to LLNL, DOE, and DoD. Additionally, we will share these data sets with outside collaborators, such as those at the Center for Subsurface Sensing and Imaging Systems, to identify NDE solutions of interest to LLNL.

We will be reconstructing the current data sets with our three current, mature algorithms: time reversal, Hilbert space inverse wave, and quantitative time-domain multiview imaging.